bioscience education

Short Communication

Using an Animal Group Vigilance Practical Session to give Learners a 'Heads-up' to Problems in Experimental Design

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Date received: 13/02/11 *Date accepted: 06/05/11*

Abstract

The design of experimental ecological fieldwork is difficult to teach to classes, particularly when protocols for data collection are normally carefully controlled by the class organiser. Normally, reinforcement of the some problems of experimental design such as the avoidance of pseudoreplication and appropriate sampling techniques does not occur until students conduct individual project work. Here, a practical session is described where students collect data on the vigilance of grazing animals, following a protocol that allows them to make typical mistakes in experimental design that are then discussed in class. Being able to explore these problems with a group of students could give valuable training in experimental design before students conduct individual projects, and therefore would be recommended as early training on fieldcourses, or as a preliminary exercise for honours projects.

Keywords: experimental design, pseudoreplication, project work, field course

Introduction

In behavioural biology, experimental design frequently relies upon observers being able to quantify the actions of animals in complex environments (Martin and Bateson, 2007). These observations need to be done with a high degree of repeatability, and often involve complex experimental designs that account for repetition of observations and attribution of characteristics to different individuals. Naïve observers conducting behavioural experiments will often generate serious problems within their experiments by sampling their data in a way that makes statistical analyses invalid, such as by failing to account for appropriate replications (Hurlbert, 1984), or by failing to truly randomise the manner in which they collect their data (since most statistical analyses rely upon data points being independently sampled: see Grafen and Hails, 2002). Teaching learners to understand these problems is difficult as a class problem, and will usually have to wait until students conduct individual projects. However, being able to explore experimental design before individual work happens can prime the students for potential mistakes, and should therefore enhance their understanding of the process of experimental design before they make an otherwise-avoidable mistake which would render project or fieldcourse work less meaningful. Understanding experimental design problems could also act to make a student more independent right from the start of individual project work.

Practical details

The practical described here relies on the well-understood concept in behavioural ecology of vigilance and group size. One of the advantages frequently cited of being social is that it reduces an individuals predation risk (Krause and Ruxton, 2002). One reason for this is that more individuals can be vigilant for predators within a group. Furthermore, as group size increases, the amount of time that each group member has to be vigilant should decrease (Elgar, 1989; Beauchamp, 2008; Rands, 2010). Individuals should still have their own interests at heart when in a group, and there may be advantages to being on the inside of the group, as an attacking predator would be expected to pick off an outside individual first (Hamilton,

1971; Rands *et al.*, 2004; Morrell *et al.*, 2011). We would therefore expect individuals on the outside of a group to be more vigilant than those on the inside. These theoretical predictions give simple hypotheses that are tested here by observing the vigilance behaviour of individual animals within grazing groups.

The practical work involves finding a herd of grazing animals (such as sheep, cows, deer, or geese), randomly selecting individual grazers, and then quantifying the amount of time that they are in a vigilant 'heads-up'position over five minutes. Each student does this four times (detailed in the Appendix), quantifying the behaviour of animals that are alone or in a group, and the behaviour of animals that are on the inside or outside of a group. From a biological perspective, this practical should work on demonstrating the hypotheses that animals should be more vigilant when they are alone or on the outside of groups, and this should be given sufficient discussion time within the class data-exploration.

In addition to reinforcement of theoretical concepts (prior classes that have been run observing sheep behaviour have demonstrated the theoretical predictions), this practical is principally designed to allow the students to experience some common mistakes in the design of behavioural experiments, and explore these through discussion in a data analysis session that occurs after data collection. To allow them to make discussable mistakes, the students should ideally collect their data in isolation from the class organiser. They are instead given their instructions for data collection in advance of the practical session (reproduced in the Appendix), which they are encouraged to think about *before* collection begins. This minimal guidance should lead to desirable diversity in how the students individually tackle the data collection. Students should ideally have the freedom to find the grazing animals themselves: this practical is therefore most suitable where the students have sufficient time to conduct the observational component on their own, and is ideal for unstructured residential fieldcourses, or classes held in rural environments (if the students are simply told to go and collect the data in advance of the data-exploration session). As a back-up, it may be sensible to identify a site where grazing animals can be found, or provide access to suitable video footage.

Discussion points during data analysis

Dependent upon where data are collected, some or all of the following discussion points may be encountered, and should be discussed with the class during the data-analysis session:

1. Inappropriate non-random sampling

Although the students are asked beforehand to think about their technique for 'randomly' selecting individuals to observe, from experience they are unlikely to do this correctly. Incorrect explanations frequently encountered include 'it was the nearest', 'it was easily recognisable', and 'I just picked one' (without clarifying how). All of these might give unexplained biases to the data collected, which are not randomly selected from a population. Other students have been found to choose individuals to sample based on the fact that they were the ones conducting vigilance behaviour when the observation session started. This is also inappropriate, as it biases the dataset towards individuals that do the behaviour, which may be unrepresentative of the population as a whole.

Some of the class may have devised techniques for randomly selecting individuals, that could involve labelling all valid individuals and selecting focals using some randomisation technique. Some of these techniques work better than others, and care should be taken to pick apart whether the techniques described are truly random. It may also be worthwhile talking about the logistic problems that arise when trying to implement truly random selection in the field on a large, moving flock of near-identical animals.

2. Repetition of observations on the same individual

If the students are searching for grazing animals in groups, it becomes increasingly likely that they may collect information from the same individual animal, and may even do this at the same time as each other (giving silent repetition of data). Repeating data, or being unable to account for data points that may be correlated because they come from the same individual, is bad pseudoreplication. This concept needs to be discussed with the class, with some guidance on how to avoid it, and what needs to be done with analyses if we know that individuals have been repeatedly sampled.

3. Structure of observations

In addition to potential pseudoreplication problems, other statistical problems could be thrown up if several flocks have been sampled, and if observations have occurred at different times. Either of these cases could mean that some data points will be correlated due to environmental or temporal factors, and this too would need to be accounted for within the structure of the statistical analysis. Class discussion time could be given to thinking about environmental factors that had a direct impact on herd behaviour, and attention should be paid to the impact the observers had on the behaviour of the grazing animals, and how this could be minimised.

4. Non-replicable results

As with any class experiment where data points are aggregated from lots of individual observations, care should be taken to explore whether individual observers were using the same criteria for scoring their data. Some students only counted individuals as being 'vigilant' if they had their heads up and were moving, whilst others counted any time when they were not grazing. Similarly, 'inside' and 'outside' may have been defined differently, and discussion should be given to what is meant by a 'group'. This means that data points collected by the same observer are more likely to be correlated with each other. One way around this problem in data analysis, which could be discussed in combination with teaching about statistical analysis, is to remove the effects of individual observer differences using parametric paired-sample *t*-tests or non-parametric paired-sample Wilcoxon's tests where each observer's data points were treated as being paired. It should be acknowledged that this type of analysis fails to take account of pseudoreplication as discussed above (meaning ideally that some form of linear modelling or multi-level modelling should be conducted), but conducting this form of analysis should demonstrate to the class whether vigilance is enhanced by being alone or in a group, or by being on the inside or outside of a group. Bringing discussion back to the behavioural biology should maybe be used to end the discussion session, leaving the students with reinforcement of the biological facts they are probably most interested in.

Therefore, this practical is designed to allow the students to take a simple set of observations that aim to test a well-known question in animal behaviour, which can then be used to illustrate some commonly encountered problems in experimental design. Because of the emphasis on mistake-making, it may therefore be sensible to consider whether the work presented here is assessed in any way, and making this clear beforehand: it is advised that this is flagged as a formative piece of work, as a diverse range of mistakes should make the discussion session much more useful as a teaching session.

Acknowledgements

Many thanks to the students and staff on the University of Bristol's BSc *Animal Behaviour & Welfare* course, for crucial criticism and comments for the development of these ideas.

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References

Beauchamp, G. (2008) What is the magnitude of the group-size effect on vigilance? *Behavioral Ecology,* **19,** 1361-1368
d.o.i. 10.1093/beheco/arn096

Elgar, M. A. (1989) Predator vigilance and group size in mammals and birds: a critical review of the empirical evidence. *Biological Reviews,* **64,** 13-33
d.o.i. 10.1111/j.1469-185X.1989.tb00636.x

Grafen, A. and Hails, R. S. (2002) *Modern statistics for the life sciences*. Oxford University Press, Oxford.

Hamilton, W. D. (1971) Geometry for the selfish herd. *Journal of Theoretical Biology,* **31,** 295-311
d.o.i. 10.1016/0022-5193(71)90189-5

Hurlbert, S. H. (1984) Pseudoreplication and the design of ecological field experiments. *Ecological Monographs,* **54,** 187-211
d.o.i. 10.2307/1942661

Krause, J. & Ruxton, G. D. (2002) *Living in groups*. Oxford University Press, Oxford.

Martin, P. & Bateson, P. (2007) *Measuring behaviour: an introductory guide* (third edition). Cambridge University Press, Cambridge.

Morrell, L. J., Ruxton, G. D. and James, R. (2011) The temporal selfish herd: predation risk while aggregations form. *Proceedings of the Royal Society B,* **278,** 605-612
d.o.i. 10.1098/rspb.2010.1605

Rands, S. A. (2010) Self-improvement for team-players: the effects of individual effort on aggregated group information. *PLoS One,* **5,** e11705
d.o.i. 10.1371/journal.pone.0011705

Rands, S. A., Pettifor, R. A., Rowcliffe, J. M. and Cowlishaw, G. (2004) State-dependent foraging rules for social animals in selfish herds. *Proceedings of the Royal Society B,* **271,** 2613-2620
d.o.i. 10.1098/rspb.2004.2906

APPENDIX:

Example of class instructions (recording sheep behaviour) given to students prior to practical work

PLEASE READ AND DIGEST THE FULL PROTOCOL BEFORE STARTING. IN PARTICULAR, points 2 and 3 require some thought beforehand, and I will be asking you about how you did this in the practical session.

I don't mind if you do this alone, in pairs or whatever, but everybody should record their own results, as we're going to group the data together in class

PROTOCOL FOR SHEEP EXPERIMENT

1. Find a field of sheep. Since your presence may have an effect upon the behaviour of the sheep, allow a few minutes (say, five) for them to get acclimatised to your presence, before conducting the next part of the experiment. Familiarise yourself with sheep grazing behaviour: standing individuals will spend long periods of time eating with their heads down, but will look up occasionally (usually whilst chewing).

You're asked to record the time during five minutes that an individual is vigilant (which we define here as not grazing with its head down). Make sure you're happy with the difference between 'head down' and 'head up'. Make notes on their general grazing behaviour. If possible, restrict your experiment to standing sheep only (unless they're all sitting!), and don't count lambs. If it's raining, it's more likely they'll all be sitting down...

2. In the first of the two experiments, you're asked to observe individuals in groups, or on their own. Devise a method for randomly selecting individuals that fit these descriptions.

3. In the second experiment, you're asked to observe individuals on the edge or in the middle of the field. Devise a method for randomly selecting these individuals.

4. Toss a coin. If it's heads, do experiment one first. If it's tails, do experiment two first. Then (obviously!) do the other experiment.

EXPERIMENT ONE: solitary versus clustered.
Toss a coin.

- If it's HEADS, start by randomly selecting a sheep on its own, and record the vigilance time over a continuous period of FIVE MINUTES.
- If it's TAILS, start by randomly selecting a sheep in a cluster of sheep, and record the vigilance time over a continuous period of FIVE MINUTES. Then, do the complementary observation (for a randomly selected solitary or clustered individual).

EXPERIMENT TWO: edge versus middle of field.
Toss a coin.

- If it's HEADS, start by randomly selecting a sheep on the edge of the field, and record the vigilance time over a continuous period of FIVE MINUTES.
- If it's TAILS, start by randomly selecting a sheep on the inside of the field, and record the vigilance time over a continuous period of FIVE MINUTES. Then, do the complementary observation (for a randomly selected individual at the inside or outside of the field).

AT THE END OF THE OBSERVATIONS you should have collected four lengths of time (in seconds) for the amount of vigilance in five minutes; one each for:

- a solitary individual
- a clustered individual
- an inside individual
- an outside individual

DON'T worry if the sheep spent all of its time being vigilant, or all of its time eating.
DON'T worry if the sheep sat down half way through (KEEP recording), or changed its status (e.g. an observer solitary sheep joins a big group of sheep halfway through the observation) -- just KEEP RECORDING, and take a note of what has happened.